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Rhizosphere engineering: Innovative improvement of root environment

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ABSTRACT

The ability of roots to extract water and nutrients from soil depends on the biophysical properties of the rhizosphere, which are strongly influenced by mucilage secretion. The aim of this study was to introduce the concept of rhizoligands to engineer the biophysical properties of the rhizosphere. A rhizoligand is defined as an additive that increases the wettability of the rhizosphere and links the mucilage network to main intimate contact with the root surface. We hypothesize that rhizoligands: i) facilitate the rewetting of the rhizosphere during repeated drying and wetting cycles; ii) enhance rhizosheath formation; iii) increase enzyme activities in the rhizosphere; and iv) increase plant biomass.

A commercial surfactant was selected as the prototype rhizoligand to test the effect on the rhizosphere biophysical properties of white lupin grown in quartz sand and subjected to six drying-rewetting cycles. Half of the plants were irrigated with water and the other half with the rhizoligand solution. When plants were 50 days old, we measured: i) soil water content; ii) rhizosheath mass; iii) activity of selected enzymes; iv) carbon content in the rhizosphere; and v) plant biomass.

Rhizoligand increased rewetting rate of the rhizosphere after drying and subsequent rewetting, resulting in a greater soil water content. Rhizosheath formation was improved in plants irrigated with rhizoligand and sand particles attached to the roots increased by 1.64 times compared to plants irrigated with water. Activity of the enzymes chitinase, sulfatase, and β-glucosidase were 4, 7.9, and 1.5 times greater in the rhizosphere of plants irrigated with rhizoligand than in the rhizosphere of plants irrigated with water. Plant biomass was 1.2 fold greater in samples irrigated with rhizoligand solution than in samples irrigated with water.

We conclude that application of rhizoligand improves plant performance by influencing the water dynamics in the rhizosphere and the plant, increasing the mechanical stability of the rhizosheaths and increasing the enzyme activities in the rhizosphere. Such effects are probably triggered by the interaction between mucilage and the applied rhizoligand, which reduces mucilage swelling (possibly by cross-linking mucilage polymers) and thus by increasing its viscosity keeps the mucilage close to the root surface. We propose the rhizoligand concept as a strategy to engineer the rhizosphere properties and to improve plant tolerance to water shortage.

1. Introduction

Water shortage has strong direct and indirect adverse effects on plant growth and crop yield. As soils dry, the transport of water and nutrients to the roots becomes limited by the low hydraulic conductivity. As the soil dries further, roots shrink and air-filled gaps form between soil and roots consequently limiting water and nutrient flow toward the root surface (Nobel and Cui,1992; McCully 1995; Carminati et al., 2009).

During soil drying microbial activity decreases (Austin et al., 2004; Sanaullah et al., 2011). Since plant–microbial interactions play a central role in nutrient availability, soil drying has a further negative impacts on the nutrient availability and uptake by plants (Hamilton and Frank, 2001; Hermans et al., 2006; Landi et al., 2006).

Increasing evidence suggests that plants modify their surrounding soil environment, the rhizosphere, to better exploit water and nutrient

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